Appendix B
Methods for identifying and evaluating pocket estuaries

Purpose

In this appendix we describe the type of habitat we are seeking to identify, the rationale, the methods and procedures for identifying these habitats, and the methods and procedures for rating or evaluating the function of these habitat types across the 11 sub-basins.

Background

"Pocket estuaries" are one of a number of important habitats for juvenile salmon in Puget Sound's nearshore environment. These features of the landscape generally punctuate otherwise linear shoreline features such as the protected or exposed shorelines, and beaches and bays, that dominate most of Puget Sound. Pocket estuaries are the result of mid to small-scale (as compared to large river deltas) interactions between marine and freshwater influence at low elevations along the shoreline. These processes create and sustain a physical structure that appears similar to large river deltas in that pocket estuaries usually contain emergent marsh, sand or mudflats, a channel structure, uplands and open water in close proximity. These features may or may not contain freshwater input.

We chose to focus on identifying, mapping and evaluating pocket estuaries because the diversity of habitat types within pocket estuaries supports a variety of fish and wildlife species including several life history stages of juvenile salmon. The channels and protected open waters provide refuge from storms and extreme events. The mixing of saltwater and freshwater in some pocket estuaries can support osmoregulation for juvenile salmon. The proximity of uplands with riparian vegetation, mudflats and sand flats supporting rich diatom growth and emergent marshes shedding detritus fuels a diverse prey base for juvenile salmon. Migratory corridor functions for juvenile salmon may be the only function not directly supported by individual pocket estuaries. However, across the landscape, the proximity of one pocket estuary to another can be measured using landscape connectivity and fragmentation metrics. The support of pocket estuaries for the migratory corridor function can only be known after the locations of pocket estuaries are mapped on the nearshore landscape.

Methods and procedures for locating and identifying pocket estuaries

In each of the 11 marine sub-basins several sources of physical landscape representations were used to locate potential pocket estuaries, confirm their existence and rate their current (observed) function (discussed below). The primary tools used to identify pocket estuaries were 1) the Department of Ecology's Digital Coastal Atlas (http://www.ecy.wa.gov/programs/sea/SMA/atlas_home.html) and 2) the DeLorme Washington Atlas and Gazetteer (1995).

General reference and named locations for each pocket estuary was obtained from a DeLorme Washington Atlas and Gazetteer. The Digital Coastal Atlas was used to identify potential targets for pocket estuaries and was the most helpful tool utilized during this exercise. This atlas allows a user to highlight and magnify any section of a Puget Sound shoreline, overlay a number of physical and biological characteristics on the magnified area, and click on a photo point to reveal a shoreline photo.

Hillshade background imagery based on a digital elevation model (DEM) was selected to scan for depressions, canyons or flat spots in the topography adjacent to the shoreline. Small bodies of water and streams intersecting or approaching the shoreline were found by selecting the 1:100,000-hydrography layer also available on the Digital Coastal Atlas. The final feature selected was the 2000-2002 oblique aerial photo layer. Selecting this layer illuminated photo points along the shoreline from which potential pocket estuary targets could be visually verified. All three layers were displayed simultaneously at an appropriate scale to scan the shoreline, identify potential pocket estuaries and verify them.

Once a pocket estuary was identified, an appropriate photo point was chosen to visually represent the feature. This photo point was recorded along with the pocket estuary identifier on the spreadsheet (discussed below) so that others can repeat the methodology, see the variability in types and sizes of pocket estuaries, and re-evaluate the attributes leading to the eventual scoring of each feature for its salmon support function. In the spreadsheet, each pocket estuary was given a two-character identifier and consecutive numbers. For example the 5th pocket estuary located in Whidbey Basin would be called WH5. In most cases, pocket estuaries were also given a name corresponding to the named map location closest to them. Latitude and longitude positions were recorded from the photo point if it was accurately centered onto the feature or from the floating cursor when centered onto a larger pocket estuary covered by several photo points.

Note: We were only capable of identifying and recording those pocket estuaries visible from Digital Coastal Atlas aerial photos. We were unable to determine the presence of any historic pocket estuaries from a photo on a computer monitor, nor was that our intention. It is expected that the locations of historic pocket estuaries cannot be located using this method because modifications to the shoreline were too severe. Potential targets identified using stream intersections often have no pocket estuary associated with them. This could be due to the slope or amount of coarse sediment in the stream preventing effective mixing of freshwater and marine processes necessary to create the pocket estuary structure.

An Excel spreadsheet was constructed to house information obtained from evaluating each pocket estuary. The **spreadsheet fields** include:

1. Existing pocket estuaries in Puget Sound (basin, pocket estuary number and name);
2. Location for mapping point data onto a WA State Plane South NAD27 projection for each pocket estuary (latitude and longitude);
3. Photo point corresponding to Ecology's 2000-2002 oblique aerial photo series;
4. Check boxes for inferred (likely) salmon functions (feeding and growth, osmoregulation, refuge) based on assumptions 1 through 4 below; check boxes for numerous stressors (shoreline development, urbanization, diking and filling, susceptibility to spills and discharges, competition from hatchery releases, aquaculture related substrate alterations, and vulnerability to sea level rise) as listed in assumptions 5 through 11; and a composite function score for each pocket estuary (properly functioning, at risk, or not properly functioning).

Assumptions

We made numerous assumptions when inferring if pocket estuaries provided a) functions for juvenile salmon, and b) presence/absence and effects of stressors. The **assumptions** include:

1. If a pocket estuary has an evident source of fresh water, we will assume it supports osmoregulation and food production,
2. If a pocket estuary has an evident channel structure or is protected by a spit or bar, we will assume it supports refuge,
3. If a pocket estuary has mudflats, intertidal marsh or eelgrass, we will assume it supports food production and refuge,
4. If a pocket estuary lacks any or all of these habitat features due to modification, we will assume the associated functions are impaired,
5. If armoring, clearing or grading and encroachment of manmade structures along the shoreline is evident, we will designate Shoreline Development is a stressor,
6. If significant urban infrastructure is evident surrounding the pocket estuary, we will assume urbanization is a stressor,
7. If diking and filling are evident, we will assume diking and filling is a stressor,
8. If marinas, industrial facilities or wastewater treatment plants are evident, we will assume spills and discharges is a stressor,
9. If pocket estuaries are adjacent to rivers with large hatchery releases, we will assume hatchery interactions are a stressor,
10. If substrate alteration as a result of aquaculture operations is evident, we will assume aquaculture is a stressor, and
11. If intertidal habitats within a pocket estuary are confined from migrating landward by manmade infrastructure, we will assume sea level rise is a stressor.

Methods and procedures for rating and evaluating pocket estuaries

A composite "score," or designation, of *properly functioning, at risk*, and *not properly functioning* were given for each pocket estuary, and was based on best professional judgment while viewing an aerial photo. These scores correspond to the inferred Chinook functions, and the number and types of stressors identified for each pocket estuary. For example, a designation of *properly functioning* was given if a pocket estuary possessed all three inferred (likely) Chinook functions, plus one or no visible stressors. A designation of *at risk* was given if three or fewer Chinook functions were evident, plus two or more visible stressors. A designation of *not properly functioning* was given if three or fewer Chinook functions were evident, plus several visible stressors. Often, this last category was attributed to pocket estuaries with no inferred Chinook functions and substantial physical stressors such as shoreline development, urbanization and diking and filling.

The oblique aerial photos also revealed a number of other landscape attributes like shoreline development, adjacent upland urbanization, presence of marinas, roads or industrial facilities that are potential sources of spills and discharges. These are the some of the stressors that are listed in number 4 under the **spreadsheet field** section and further contexted in assumptions 5 through 11. If any of these were observed while reviewing an aerial photo of the pocket estuary and surrounding landscape, then an X was placed in the appropriate field under the appropriate column header.

Using this method consistently throughout Puget Sound will likely produce similar results. However, users should be familiar with the variability of Puget Sound's shorelines, have some local knowledge of certain features they see on oblique aerial photos and understand the interactions between water, sediment and the underlying geologic landscape in bringing about features such as pocket estuaries. Functions for salmon, however, may be more subjective, especially since the functions are inferred from opportunities observed from the air and not empirical data on salmon feeding, refuge or osmoregulation.